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ABSTRACT

This discussion of the use of various delivery systems and models of instruction for technical training in the field of measurement and control includes a review of the basic requirements of a learning system. Several aspects of such a system are considered, i.e., the design of a learning system through the use of computer assisted instruction, the development of physical models to facilitate learning, and the use of simulation in the delivery of instruction. (RAO)

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INSTRUCTIONAL SYSTEMS UTILIZING MODELING AND SIMULATION FOR TECHNICIAN TRAINING IN THE AREA OF MEASUREMENT AND CONTROL

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INSTRUCTIONAL SYSTEMS UTILIZING MODELING AND SIMULATION FOR TECHNICIAN TRAINING IN THE AREA OF MEASUREMENT AND CONTROL

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Today's rapidly changing technology in the fields of measurement and control requires that a more efficient instructional delivery system be developed to provide faster and more economical training of the technician. A systematic system involving hands-on training has been responsible for the success of many programs. Hybrid computer systems are currently available that can be used to improve the utilization of all available teaching resources. These same computers may alsc be used to provide instruction or to simulate a complicated process system. The computer, along with physical models, can accelerate the learning process and result in higher levels of learning.

1. INTRODUCTION

Today's technology has created a special class of worker generally titled "technician", who often has to interface with the production and engineering departments. The need to be practical, but understand some abstract concepts requires a specialized type of instruction that is rich in "hands on" experiences. With our rapidly increasing technology this specialized training need has reached major proportions, requiring the investment of large amounts of capital as both educational institutions and industries try to fill this need. Some attempts at training have been more successful than others primarily because of their educational soundness. The pivitol point in technical education occurred over 100 years ago when Victor Della Vos worked out a new system for the teaching of the mechanical arts at the Imperial Technical School at Moscow, Russia. His was the first documented system to use scientific principles in analyzing the mechanical arts, and based courses of instruction on these analyses. This radically altered how mechanical subjects were taught. In the mid nineteenth century, the prevailing method of learning a trade or manual art

was through the imitative method of apprenticeship, resulting in a specialized craftsman after a great deal of time had been spent, quite often in non-productive tasks. As machinery became more complex, speed of production became a major factor making a shorter training time much more important. Della Vos, realizing this need, reasoned that the mastery of any art is readily attained when each student masters the elements of the art, one at a time, in sequence that progresses from easy to hard. The goals of this new system were to teach the fundamentals of the mechanical arts:

a) in the least possible time
b) in such a way as to give adequate instruction to a large number of students at one time
c) by a method that would give the study of practical work a sound, systematic acquirement of knowledge
and d) in a manner by which the teacher could determine the progress of each student at any time.

When this systematic system of instruction was shown at the Centennial Exposition in Philadelphia in 1876, John Runkle (Massachusetts Institute of Technology, Boston, Massachusetts) and Calvin Woodward (Washington University, St. Louis, Missouri) were quick to see its potential, and were the leaders in establishing this form of education in the United States. Today, this system underlies the basic fabric of most current technical education. The more recent emphasis on programmed texts was an attempt to follow the guide of ordering the course material into small units to be sequentially learned. Its major limitation is its passivity. Even the best-intentioned individual has difficulty maintaining the self-discipline required by these texts.

Requirements of a Learning System

Knowing that an individual's learning can be enhanced by multisensory involvement, an extremely effective situation can be created by marshalling the techniques of programmed learning along with the use of an active model or simulation geared toward a specific learning objective. The technology of the computer can be used as an aid in this effort. The system created is equally operable in an educational institution or in an industrial setting. A major effort must be made by the instructional manager to define specific instructional objectives as the basis for improving instruction.

Three major requirements of a managed learning system are:

a) an active response by the student
b) an immediate knowledge of the results of the response
c) the latitude for individual self-pacing

Managed learning depends on repeatable, planned sequences of instructional events designed to produce measurable and consistent effects on each participating student.

Once the objectives are established the computer can be utilized as a resources manager using an item bank, an interactive randomly selected testing capability, and individualized evaluation-based prescriptions to help each student measure progress and identify what remains to be learned. This process will involve minimal supervision, enabling the instructional manager more time to work with the special needs exhibited by some students.

The effect is the creation of a variety of different learning experiences. Computers are not the only instruments in this system, but the concentration of this paper centers on their involvement.

The phenomena that sets this technique apart from other approaches is the individualized management of the technical education each person receives. As the cost per computing unit is reduced, and with the availability of ever more sophisticated units, there will be an explosive use of computers for training purposes that will eclipse each past year's use, and make today's training techniques appear to be quite awkward. This growth potential should not delay implementation. The use of computers in educational settings is a continuous learning process; a time of evaluation, re-evaluation, and redevelopment.

Each modern educator has a wealth of multi-sensory teaching materials currently available, and can, by employing lateral thinking, set up local specific programs based on individual goals and experiences. The breakthrough comes when the instructional manager no longer relies on a single form of delivery for each student. With this acceptance, the computer no longer functions exclusively in drill and exercise tasks.

Currently there exists a very wide range of computer systems as well as a sufficient range of languages for the educator's purpose. This paper will not stress any one computer system, or any particular language, although in some specific examples one may be mentioned. Almost any computer will do any application if cost and performance are not factors. A mini computer can usually do the job of a large computer if enough time and memory is provided. The time factor becomes a major limiter in real-time applications. Each language has advantages and disadvantages when compared to another, and many projects have been set aside because of tunnel vision concerning a specific hardware or software consideration.

Most of the success of a computer managed system comes from a knowledge of the task the instructor wishes to have mastered. A properly managed system will provide

1) ample equipment accessibility
2) a complete record keeping system
3) suggested alternate learning paths

Computer Assisted Instruction (CAI)

The general philosophy used in building a course involves selecting a content area, specifying instructional objectives, creating a hierarchy of objectives, performing a task analysis, dividing the content area into small units, and developing instructional modules in which the student is required to participate, eg. to answer questions. The student's answer is then compared against known correct answers and anticipated wrong answers. Once the student responds the program may give immediate encouragement for correct answers or constructive comments about why the answer is wrong so that misinformation is not retained. If necessary, additional reading or study assignments may be assigned or the student may be directed to a conference with the instructor. A well written course using CAI will control the path a student takes through a course, modifying this path according to the student's performance.

Consider the following example. Assume a learning objective requires an individual to make accurate readings on a multi-scale analog volt meter. A CAI course would pre-test the individual for competency. The criterion for success might be three successive correct responses within two percent accuracy on each of the meter's scales. If the individual is successful, this completes the task, the success is logged into the system file, and the individual is commended for the completion. If unsuccessful, the individual is routed through training on the specific meter. This training might be accomplished on a computer graphics terminal, with printed text, or with the actual meter and an instructor. After completing the training, the individual is re-tested with the appropriate records kept of the number of trials and errors. Incidently, an analysis of these records may suggest where improvements in the training materials are needed. If speed of response is an additional criteria, this type of system can be structured to include a timing of the response. The computer can be used to generate the random voltages the individual will read, thereby eliminating the possibility of pre-knowledge of the test items.

This same format can be used in teaching accurate reading techniques for a number of measurements such as voltage, current, decibels, resistance, and oscilloscope readings including phase, magnitude, and frequency. The limitation to these tasks involves the availability of digital to analog and analog to digital interfaces to the computer controlling the learning experience. Depending on its configuration, this type of task could be accomplished on a microprocessor, a minicomputer, or a large scale computer system. In some cases two separate stand-alone computers could be used with one system handling the analog-digital conversions and the other controlling the overall management function. The student would perform the interface function between the two systems as is often required in industrial applications.

There are several special CAI languages such as Coursewriter, PLATO, PASCAL and a version of PILOT that can be used on an inexpensive microcomputer, that are specifically designed for the type of course construction described.

In this example a computer has been assigned the tasks of managing the resources available to the student, of keeping records on the progress, and of routing the student through the most productive learning sequence available. This technique requires that organization of the learning experience be well defined and complete. The student actively participates in a situation that involves all of the senses simultaneously. The end result should be a very positive learning experience with a very high retention rate, and it will be testable.

Physical Modeling

Many classical learning situations involve the use of physical models. Physics employs such items as pulleys, levers, and inclines; Chemistry uses three-dimensional models of molecular structures; Biology uses the fetal pig to teach the anatomical systems of the human. Models can be used to enhance the learning by changing the scale size so complex interactions can be viewed simultaneously. In the following example instruction in the necessary programming methods has been given.

An H-O scale model railroad loop is constructed and the student is assigned the task of operating a train of a given mass, starting from rest, ramping to a scale speed for a number of scale distance units, and ramping back to a stop position. Additionally, the student should be able to predict where these events will occur within a specific tolerance factor. A computer system is utilized to accept the students' program, perform the program, and verify the accuracy of the predictions. This model allows the student to handle a real-time application, and to better actualize the differences involved in calculations and measured parameters. The student develops a program design to accomplish a specific hardware task involving the physical laws and measurements and experiences some of the effects of applied electronics. Obviously, this is a more advanced learning experience used after instruction in feedback systems has been accomplished. The management functions of the computer system allows each student to test the effects of the program at an individual rate independent of the availability of an instructor. When major difficulties occur, individualized attention can be prescribed and administered. This model of a complex system is extremely low cost and actively involves the total student. The experiences gained are transferrable to any real-time feedback system.

Simulation

Although actual experience is the best teacher, reality in education must often give way to such factors as equipment availability, safety, time and cost. As a high level sub-

stitute, the computer can simulate many conditions virtually impossible to duplicate in an educational setting. The most common example of training simulation is the flight simulator used in pilot training. Emergency conditions can be duplicated without the obvious risk factor being present. As such it provides an ability to create an illusion so realistic that the desired effect is duplicated, providing an educationally rewarding experience. During the design phase of a system involving complex or hard to change components such as those found in the petro-chemical industries, the computer based simulation becomes highly cost effective. Software changes can be manifested into eventual hardware construction.

The following example can be effectively managed on a computer system with interactive graphics. Consider a chemical process involving the reaction of two chemicals under controlled temperature conditions and proper agitation to form a product. This entire process can be simulated on the computer. Computer generated graphics permit the student to "see" the system change with time. Items the student can change and observe the subsequent results include:

a) the primary flow measurement elements
b) the method of control, including the placement of the final control elements
c) the level measurement system
d) the reactor temperature measurement and control system

Each element or system the student selects has its own characteristics of speed and accuracy that are typical of actual elements or systems. Additionally, the student has available graphic capability to construct Bode plots of the system to predict the system stability. The student's task might be to optimize the system to produce the best output with minimum waste.

A properly managed system will record what attempts were made in the optimization process, and an analysis of these can be used to shape a more logical thought process for the student in a design application.

In a modification of this tactic, depending on the objectives and cost allocations available, a training program for system operators could be established. Such a program might include a completely instrumented control panel. Conditions could be simulated such that the instruments indicated a specific condition requiring operator action. The appropriateness of the action taken and the rate of response could be recorded and used as an evaluative tool. Such elaborate systems would have to be carefully evaluated for their cost-effectiveness, but may prove to be highly beneficial in high risk environments.

Many forecasts predict a greater use of computers in the educational process as the industry develops inexpensive and reliable terminals. Graphical applications of computers are

growing at a very rapid rate. During the 1980's small but immensely powerful personal computers may become as much a part of our lifestyle as the television, the telephone, the printed paper, and the notebook. This computer presence has a tremendous potential for the improvement of the process of learning.

Conclusions

The examples presented in this paper were generalized enough so that the concepts were not obscured by the details of implementation. Each system requires an allocation of time resource and the development of local programs based on existing or future computer acquisitions.

Each system attempted to provide actual "hands-on" training experiences and to focus on specific learning objectives. Each system also stressed the involvement of a computer as a management tool. The computer applications were a part of an integrated instructional process.

Through the thoughtful management of the total instructional resources available, the educational manager can achieve a higher level of learning among the technical personnel in a shorter period of time, and in a highly cost-effective manner.

The hardware is now available. What is needed is an imaginative use of what we have. The need for development is present. The question remains: Is the need strong enough to pressure the imagination into practical invention?

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